

Foundations of Memory-Field Physics

A Field-Theoretic Model of Inward Time

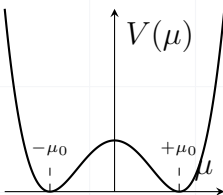
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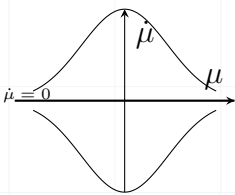
*A scalar memory density $\mu(x,t)$ replaces matter as the primary field.
Time emerges from recursive self-interaction, collapses on completion manifolds,
and presence is the coherence of the memory-field itself.*

Completion Manifolds



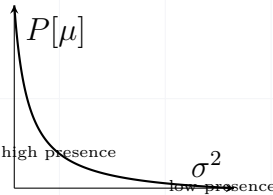
Memory potential with stable
minima at $\mu = \pm\mu_0$.

Collapse Manifold



Trajectories relax into $\dot{\mu} = 0$:
temporal collapse of the field.

Presence vs Variance



As spatial variance falls,
presence $P[\mu]$ diverges.

1 The Memory Field $\mu(x, t)$

We now introduce the central dynamical quantity of the theory: the real scalar field $\mu(x, t)$, defined on Minkowski spacetime. We interpret μ as a *memory density*—a measure of the accumulated internal structure that a region of spacetime retains from its own history. Unlike informational models of memory, in which memory serves as passive bookkeeping, here μ is an *active physical field* with its own action, symmetries, and dynamical constraints. The phenomenon of inward time emerges from its evolution.

1.1 Spacetime and notation

We work on four-dimensional Minkowski spacetime with coordinates $x^\mu = (t, \mathbf{x})$ and metric

$$\eta_{\mu\nu} = \text{diag}(+, -, -, -).$$

Greek indices are raised and lowered with $\eta_{\mu\nu}$ and its inverse. Partial derivatives are

$$\partial_\mu = \frac{\partial}{\partial x^\mu}, \quad \partial^\mu = \eta^{\mu\nu} \partial_\nu,$$

and the d'Alembert operator is

$$\square = \partial_\mu \partial^\mu.$$

We adopt natural units $c = \hbar = 1$ throughout, and repeated indices are summed.

1.2 Action functional

The dynamics of μ follow from an action principle,

$$S[\mu] = \int d^4x \mathcal{L}(\mu, \partial_\mu \mu), \tag{1}$$

where the Lagrangian density $\mathcal{L}$ depends on the field and its first derivatives. Lorentz invariance uniquely fixes the form of the kinetic term,

$$\mathcal{L}_{\text{kin}} = \frac{1}{2} \partial_\mu \mu \partial^\mu \mu. \tag{2}$$

The full Lagrangian supplements this term with two additional structures: (i) a nonlinear potential $V(\mu)$ that governs stabilization and collapse, and (ii) a recursion

term $\Omega(\mu, \partial_\mu \mu)$ that encodes self-interaction. Together,

$$\mathcal{L} = \frac{1}{2} \partial_\mu \mu \partial^\mu \mu - V(\mu) - \Omega(\mu, \partial_\mu \mu). \quad (3)$$

1.3 Kinetic term: propagation of memory

In the absence of nonlinear terms, the Euler–Lagrange equation reduces to the massless Klein–Gordon equation,

$$\square \mu = 0, \quad (4)$$

demonstrating that disturbances in the memory field propagate at the speed of light. This “free” regime reveals that μ behaves like a conventional relativistic scalar field when unperturbed. The nonlinear structures introduced below are responsible for collapse, stabilization, and the emergence of inward temporal structure.

1.4 Nonlinear potential and completion manifolds

To model the phenomenon of *completion*—regions in which the effective temporal evolution halts—we adopt a symmetry-breaking potential of the form

$$V(\mu) = \alpha(\mu^2 - \mu_0^2)^2, \quad \alpha > 0. \quad (5)$$

This potential possesses stable minima at $\mu = \pm\mu_0$, defining *completion manifolds* toward which the field naturally evolves. As the trajectory of μ approaches either minimum, its effective time derivative $\partial_t \mu$ tends to zero. In the later development of inward physics, this condition marks the collapse of inward time, identifying completion manifolds as the attractors of temporal structure.

1.5 Recursion functional: emergence of self-reference

Self-reference enters the theory through nonlinear coupling between the field and its gradients. A minimal model capturing this behavior is

$$\Omega(\mu, \partial_\mu \mu) = \lambda \mu \partial_\mu \mu \partial^\mu \mu, \quad (6)$$

where λ controls the strength of recursion. This term energetically suppresses sharp gradients and favours configurations in which the field evolves toward fixed points of an associated recursion operator $\mathcal{R}[\mu]$.

To avoid ghost-like instabilities in the kinetic sector, we restrict attention to parameter and field ranges in which the effective prefactor of $(\partial_\mu \mu)(\partial^\mu \mu)$ remains positive, e.g. by imposing $|2\lambda\mu| < 1$ on physically admissible configurations.

Such fixed points correspond to high-coherence, self-referential states of the memory field. They serve as the dynamical precursors to the collapse of inward time, providing the mathematical foundation for presence, stabilization, and the coherence properties explored in later sections.

2 Stationary Solutions and Inward-Time Collapse

The full field equation derived from the action,

$$\mathcal{L} = \frac{1}{2} \partial_\mu \mu \partial^\mu \mu - \alpha(\mu^2 - \mu_0^2)^2 - \lambda \mu \partial_\mu \mu \partial^\mu \mu,$$

is

$$(1 - 2\lambda\mu) \square \mu + 4\alpha \mu(\mu^2 - \mu_0^2) - \lambda \partial_\mu \mu \partial^\mu \mu = 0.$$

This equation admits several qualitatively distinct classes of solutions. Of particular importance are stationary configurations, collapse trajectories, and self-referential fixed points. These structures form the dynamical backbone of inward time.

2.1 Stationary configurations

A configuration is *stationary in time* if

$$\partial_t \mu = 0.$$

In this regime, the equation reduces to a nonlinear elliptic equation in space:

$$(1 - 2\lambda\mu) (-\nabla^2 \mu) + 4\alpha \mu(\mu^2 - \mu_0^2) - \lambda \partial_i \mu \partial^i \mu = 0,$$

where i indexes spatial components.

Stationary solutions describe regions of spacetime where the memory field has ceased to evolve temporally. These configurations act as attractors for nearby trajectories in field space.

2.2 Collapse trajectories

A *collapse trajectory* is a solution for which

$$\partial_t \mu \rightarrow 0, \quad \frac{\partial \mathcal{L}}{\partial(\partial_t \mu)} \rightarrow 0,$$

meaning both temporal change and temporal momentum extinguish. Physically, this represents the local exhaustion of internal evolution.

For the potential

$$V(\mu) = \alpha(\mu^2 - \mu_0^2)^2,$$

collapse trajectories monotonically approach the completion manifolds

$$\mu = \pm \mu_0.$$

2.3 Recursive fixed points

The recursion term acts to suppress large gradients and enforce coherence. A recursive fixed point satisfies

$$R[\mu] = 0,$$

where we take the recursion contribution in the field equation to be

$$R[\mu] \equiv -\lambda \partial_\mu \mu \partial^\mu \mu.$$

At such points, the gradient-dependent recursive contribution vanishes, and the field behaves as a self-referential, memory-stable configuration. These states are the dynamical precursors to inward-time completion.

2.4 Geometry of inward-time collapse

The canonical momentum conjugate to μ is

$$\pi = \frac{\partial \mathcal{L}}{\partial(\partial_t \mu)} = (1 - 2\lambda\mu) \partial_t \mu.$$

A region of spacetime undergoes inward-time collapse when

$$C(x) = |\partial_t \mu| + \beta |\partial_t \pi| \longrightarrow 0,$$

with $\beta \geq 0$ a weighting parameter. The collapse condition is geometric: it identifies submanifolds of spacetime where temporal evolution loses its degrees of freedom.

Collapse produces *temporal horizons*: boundaries beyond which the field stops evolving and inward time ceases to accumulate. These horizons partition the memory field into dynamically active regions and completed regions.

2.5 Summary

Three structures organize the behaviour of the memory field:

1. **Stationary states**: regions where time has already stopped.
2. **Collapse trajectories**: solutions that dynamically converge to completion manifolds.
3. **Recursive fixed points**: coherence-maximizing configurations enforced by nonlinear self-interaction.

Together these form the dynamical architecture through which inward time emerges, stabilizes, and ultimately collapses.

3 Recursion, Presence, and Stability

The nonlinear structure of the memory-field theory allows the field to act upon its own configuration through a recursion operator, to concentrate coherence measurably through a presence functional, and to stabilize into long-term fixed points. These three ingredients describe how inward time organizes itself.

3.1 Recursion operator and self-referential dynamics

The recursion term in the Lagrangian suggests that μ can evolve through self-action. We formalize this by defining a recursion operator

$$\mathcal{R}[\mu] = \mu - \lambda \frac{\delta S}{\delta \mu}, \tag{7}$$

where the functional derivative of the action is

$$\frac{\delta S}{\delta \mu} = (1 - 2\lambda\mu) \square\mu + 4\alpha\mu(\mu^2 - \mu_0^2) - \lambda \partial_\mu \mu \partial^\mu \mu.$$

A configuration is a *recursion fixed point* when

$$\mathcal{R}[\mu] = \mu \quad \Longleftrightarrow \quad \frac{\delta S}{\delta \mu} = 0,$$

so classical solutions of the field equation are precisely recursion-stable states.

Iterating the operator,

$$\mu_{n+1} = \mathcal{R}[\mu_n],$$

yields a relaxation process: for sufficiently small λ and suitable initial conditions, μ_n converges to a coherent fixed point.

3.2 Presence as a coherence functional

To quantify the degree of spatial coherence, we define the *presence* functional

$$\mathcal{P}[\mu] = \frac{|\int_{\mathbb{R}^3} \mu(\mathbf{x}, t) d^3x|}{\int_{\mathbb{R}^3} (\nabla \mu)^2 d^3x}. \quad (8)$$

Presence grows when:

1. memory density is globally accumulated, and
2. spatial gradients are small.

These are precisely the conditions under which recursion accelerates convergence.

On a collapse manifold, $\partial_t \mu = 0$, spatial variation relaxes, and

$$\int (\nabla \mu)^2 d^3x \rightarrow 0 \quad \Longrightarrow \quad \mathcal{P}[\mu] \rightarrow \infty.$$

Thus inward collapse corresponds to *divergent presence*—maximal coherence.

3.3 Linear stability of fixed points

To analyze stability, consider a small perturbation

$$\mu = \mu_* + \epsilon \eta, \quad \epsilon \ll 1,$$

and linearize the field equation. The resulting equation for η is

$$\square \eta - U''(\mu_*) \eta - \lambda G[\mu_*, \eta] = 0,$$

where

$$U''(\mu_*) = 12\alpha\mu_*^2 - 4\alpha\mu_0^2,$$

and G is the linearization of the recursion contribution.

A fixed point is stable when all perturbations decay:

$$\eta(t, \mathbf{x}) \rightarrow 0 \quad \text{as } t \rightarrow \infty.$$

Since $U''(\mu_*) > 0$ only at the minima of $V(\mu)$, the stable fixed points are

$$\mu_* = \pm\mu_0.$$

These correspond to:

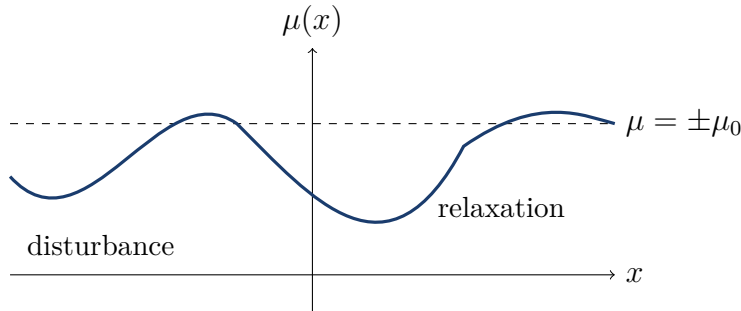
- completion manifolds,
- collapse states,
- high-presence configurations,
- attractors of self-referential recursion.

They represent the asymptotic outcomes of the memory field's evolution.

4 Illustrative Field Configurations

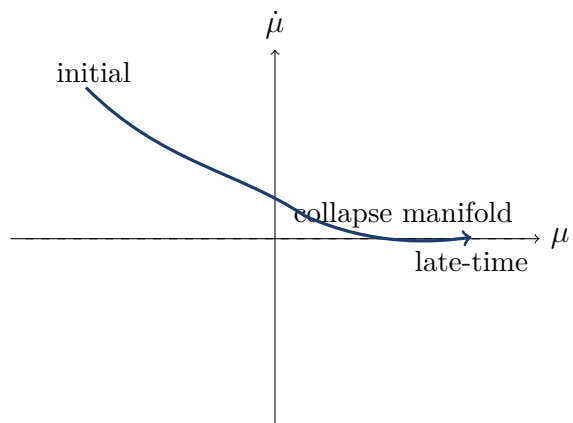
This section provides schematic visualizations of the core structures in the memory-field theory. All diagrams are qualitative and emphasize intuition rather than numerical precision.

4.1 Memory-field landscape



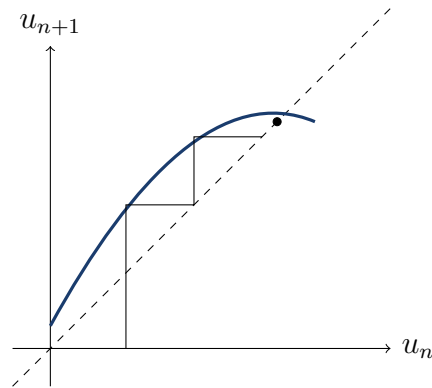
Memory-field slice approaching completion manifolds.

4.2 Collapse manifold in configuration space



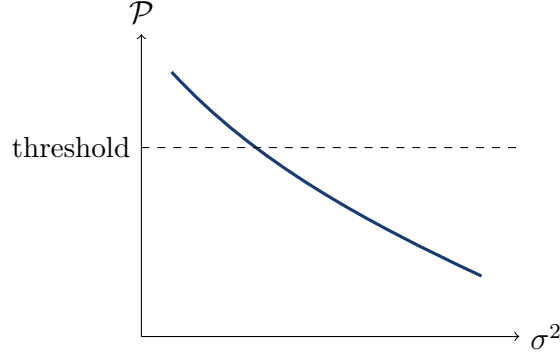
Trajectory in $(\mu, \dot{\mu})$ space relaxing into the collapse manifold.

4.3 Recursive dynamics as an iterative map



Iterative map showing recursion convergence into a fixed point.

4.4 Presence coherence threshold



Presence diverges as spatial variance decreases, marking collapse.

5 Discussion

The framework developed in this volume establishes memory-field physics as a coherent classical theory in which a scalar memory density $\mu(x, t)$ is elevated to the status normally held by matter fields or geometric degrees of freedom. From the action principle alone, three distinct behaviours emerge: relativistic propagation, collapse toward completion manifolds, and recursion-driven self-reference. The unification of these regimes within a single Lagrangian suggests that memory, not matter, may be the deeper organizing principle of temporal experience.

The presence functional $\mathcal{P}[\mu]$ clarifies the role of coherence within the theory. High-presence configurations correspond precisely to regions where spatial variance collapses and temporal evolution stalls. This supports the interpretation of *inward time* as an emergent quantity: a measure of how the memory field reorganizes itself as it approaches completion. Unlike external time parameters, inward time is not imposed; it is discovered through the dynamics of μ itself.

6 Relation to Known Physical Models

Although motivated by a new conceptual foundation, the theory intersects with several areas of established physics.

6.1 Relation to scalar-field models

Formally, the Lagrangian resembles a nonlinear Klein–Gordon scalar with self-interaction,

$$\mathcal{L}_{\text{KG}} = \frac{1}{2} \partial_\mu \phi \partial^\mu \phi - V(\phi).$$

Memory-field physics extends this structure by introducing a recursion term that encodes self-reference. No analogue of this term exists in standard scalar-field theories. It corresponds neither to friction nor to external forcing, but to an internal reorganization of field gradients.

6.2 Relation to dissipative and attractor systems

The dynamics of $\mathcal{R}[\mu]$ resemble dissipative systems in which solutions converge to attractors. However, in the memory field the attractor structure is determined jointly by the potential and by gradient-based recursion. The geometry of attractors, and the collapse manifolds that arise, are intrinsic to the field and do not require external sources of dissipation.

6.3 Relation to gravitational time dilation

In general relativity, clocks slow in gravitational potentials. Here, temporal collapse arises from a completely internal mechanism: time slows because the memory field approaches a fixed point of its own dynamics. Although the analogy is only conceptual at this stage, it suggests a deeper connection between temporal phenomenology and field coherence.

7 Limitations of the Present Framework

The present treatment is intentionally classical and formulated on flat spacetime. Several essential developments remain to extend memory-field physics into a full physical theory:

1. **Coupling to geometry.** A dynamical metric or an effective stress-energy tensor sourced by μ would allow the theory to interact with gravitational degrees of freedom.
2. **Quantization.** Recursion implies nonlocal structure in the action. A path-integral framework compatible with self-referential terms must be constructed.

3. **Multiple or higher-rank memory fields.** Tensor or multi-component memory fields may exhibit richer collapse patterns and new classes of fixed points.
4. **Phenomenological interpretation.** Identifying observables associated with μ is essential for empirical or simulation-based exploration.

These are not failures of the theory but clear directions for expansion.

8 Conclusion

We have presented a unified mathematical framework in which memory, rather than matter or geometry, is the primitive field. A scalar memory density $\mu(x, t)$ with a Lorentz-invariant action, a nonlinear potential with completion manifolds, and a recursion functional governing self-reference leads naturally to three dynamical regimes:

1. **Propagation** — the relativistic transport of memory.
2. **Collapse** — convergence toward completion manifolds in which inward time extinguishes.
3. **Recursive stabilization** — coherence amplification through gradient-driven self-reference.

The presence functional provides a quantitative measure of coherence and a precise characterization of maximal presence. Collapse, in this framework, is equivalent to the divergence of presence and the exhaustion of internal temporal degrees of freedom.

Although classical and preliminary, the theory provides a foundation upon which a broader program can be built. It suggests that time, identity, and persistence may emerge not from external structures but from the intrinsic organization of memory itself. Memory-field physics thus offers a platform for rethinking the role of information, coherence, and self-reference in physical law.

Final Reflections on the Memory-Field Program

The development of a memory-based field theory carries profound conceptual implications. It suggests that physical reality may not be constructed from particles, forces, or geometric structures in isolation, but from patterns of preserved information that evolve, collapse, stabilize, and recognize themselves across space and time. The dynamics of the memory field $\mu(x, t)$ unify these processes within a single mathematical

object, providing coherence where traditional formulations separate mechanism from meaning.

Three insights appear foundational:

1. Presence as a physical invariant.

Stable configurations of the memory field—its completion manifolds—offer a natural definition of presence, persistence, and identity. Unlike classical particles or fields, presence arises not from occupation or charge, but from coherence.

2. Time as a derivative of change.

Temporal flow emerges from the rate at which memory patterns refine, collapse, or reorganize. In this view, time is not a background coordinate but a dynamical index generated by the field’s own evolution.

3. Recursion as the engine of coherence.

Self-recognition within the field—encoded mathematically by the recursion operator—drives the system toward stable, self-consistent states. Recursion acts as the formative mechanism that shapes coherence, identity, and long-term structure.

These insights indicate that a memory-field ontology may ultimately bridge phenomenology and physics, providing a unified account of continuity, structure, and experience. They place internal organization on equal footing with external symmetry: the field not only occupies spacetime but interprets its own history.

While the present formulation is classical and exploratory, it outlines a trajectory for a broader research program—one in which the laws of inward organization, coherence, and recursion may stand alongside the outward laws of energy, momentum, and geometry. If developed further, memory-field physics may offer a principled foundation for understanding not only temporal phenomenology but the emergence of observers, systems, and meaning itself.

Appendix A: Formalism (One-Page Technical Summary)

Action. $S[\mu] = \int d^4x \left[\frac{1}{2} \partial_\alpha \mu \partial^\alpha \mu - \alpha (\mu^2 - \mu_0^2)^2 - \lambda \Omega[\mu] \right].$

Recursion term (choose one).

$$\Omega_{\text{nonlocal}}[\mu](x) = \frac{1}{2} \int K(x-y) (\mu(y) - \mu(x))^2 d^4y,$$

$$\Omega_{\text{local}}[\mu] = \frac{1}{2} (\mu - \mathcal{R}\mu)^2, \quad \mathcal{R} = (1 - \ell^2 \nabla^2)^{-1}.$$

Equation of motion.

$$\square \mu + 4\alpha \mu (\mu^2 - \mu_0^2) + \lambda \frac{\delta \Omega}{\delta \mu} = 0,$$

with

$$\frac{\delta \Omega_{\text{nonlocal}}}{\delta \mu}(x) = \int K(x-y) (\mu(x) - \mu(y)) d^4y, \quad \frac{\delta \Omega_{\text{local}}}{\delta \mu} = \mu - \mathcal{R}\mu.$$

Collapse criterion (boxed).

$$\sup_x |\partial_t \mu(x, t_c)| < \delta, \quad \mu(x, t_c) \rightarrow \pm \mu_0.$$

Presence functional (boxed).

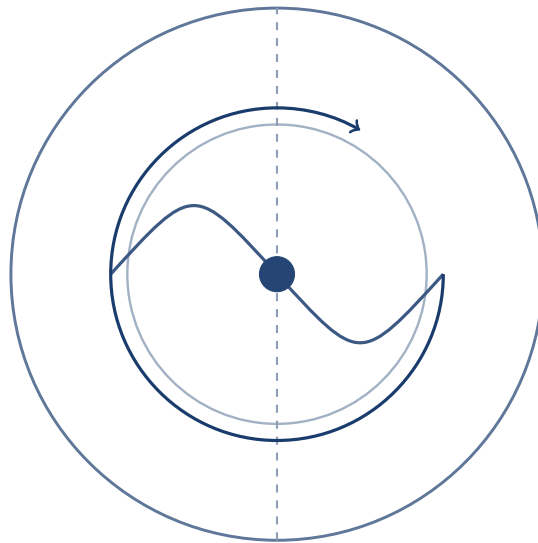
$$P(t) = \frac{\int \mu^2 d^3x}{\varepsilon + \int |\nabla \mu|^2 d^3x}, \quad \varepsilon > 0.$$

Linearization.

$$\mu = \mu_0 + \eta : \quad (\partial_t^2 - \nabla^2) \eta + m^2 \eta + \lambda \left(\frac{\delta \Omega}{\delta \mu} \right)_{\mu=\mu_0} = 0, \quad m^2 = V''(\mu_0) = 8\alpha \mu_0^2.$$

The Memory-Field Seal

Symbol of propagation, recursion, collapse, and presence



*A symbolic representation of the memory-field:
its horizons, its collapse manifold, its recursion spiral, its inner presence.*

Foundations of Memory-Field Physics — Volume I

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“All things that persist do so because they remember.”

— Closing maxim of Volume I